Renewable and Sustainable Energy Reviews 30 (2014) 420–428

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Sustainable energy development – Lithuania's way to energy supply security and energetics independence

Vladislovas Katinas*, Antanas Markevicius, Eugenijus Perednis, Juozas Savickas

Lithuanian Energy Institute, Laboratory of Renewable Energy, Breslaujos str. 3, LT-44403 Kaunas, Lithuania

ARTICLE INFO

Article history:
Received 19 April 2013
Received in revised form
3 September 2013
Accepted 22 October 2013
Available online 14 November 2013

Keywords:
Renewable energy
Biomass for CHP
Electricity
Feed–in tariff
Heat
Biofuels for transport
Environmental impact

ABSTRACT

In this article, the possibility to increase the use of renewable energy for the production of heat, electricity, the use of biofuels for transport and energy policy is analyzed. In Lithuania the energy demand is constantly increasing, the increase in traditional fuels for energy generation continues to increase the impact on environment. The share of production renewable energy for all EU Member States until 2020 is indicated in Directive 2009/28/EC. The target for Lithuania is 23% in gross final energy consumption. In Lithuania the annual gross inland consumption of energy during years 2001 to 2010 varied from 8.22 to 9.22 Mtoe. The share of renewable energy sources increased approximately from 8.3% to 18.1%. In 2011 the gross inland consumption of imported fossil fuel comprises 81.7% and local fuel – 18.3%. The Lithuanian government has prepared and legislated acts and programs, both for the promotion of renewable energy use and increase the use of this ones in the country. The most important obstacles for faster growth of renewable energy use are high investment costs, long pay-back periods for projects, a lack of the financial resources necessary to implement governmental policies and a comparatively fast increase in prices for alternative fuels. Recently in Lithuania, renewable energy compromises about 18% of gross inland consumption of energy and about 0.3% local fuel or other fossil fuels are mainly imported from Russia. The increase of use renewable energy will improve the security of energy supply in Lithuania and also enable to reduce above 8% a greenhouse gas emission.

Contents

* Corresponding author. Tel.: +370 37 401841; fax: +370 37 351271.
E-mail address: res@mail.lei.lt (V. Katinas).

1364-0321/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2013.10.033

1. Introduction

There are obvious reasons for increasing the share of renewable energy sources (RES) in the European Union (EU). The objectives of the EU Member States are to change their policy in order to significantly increase the use of renewable energy in such sectors: heating and cooling, electricity production and transport. EU Member States are called upon to ensure rapid, fair and simple authorization procedures for RES, improve pre-planning mechanisms in which regions and municipalities must assign suitable locations for the deployment of RES and integrate these into their regional and local action plans [1]. These measures will improve energy security, mitigate greenhouse gas emissions and reduce regional and local pollutants from the energy sector [2,3]. For these reasons, the EU set a target for Lithuania to source 23% of its gross final energy consumption from RES by 2020. Each EU Member State has a national target for energy production from RES to contribute towards the overall target. EU Member States are free to choose their preferred support mechanism to achieve their target [3]. In EU the use of RES is seen as a key element in energy policy, reducing the dependence on fuel from non-member countries, reducing emissions from greenhouse gas, and energy costs from oil prices. The date of Eurostat shows that from 1997 to 2007 installed capacity for electricity generation from RES increased by 54% in EU-27. Therefore wind capacity increased twelvefold in this period. Wood capacity and the capacity of other RES as well as geothermal, photovoltaics, municipal solid waste and biogas – exhibited an almost threefold and a fivefold increase respectively [4,5]. The capacity of hydro maintained the largest share of the total over the last ten years. However, its share fell from 91% in 1997 to 62% in 2007 in favor of wind capacity, which grew from a 3% share in 1997 to a 25% share in 2007 [4–7]. Wood and wood waste continues to make the largest contribution to the share of energy from renewable sources in gross inland energy consumption. In EU the use of renewable energy is seen as a key element in energy policy, reducing the dependence on fuel from non-member countries, reducing emissions from carbon sources, and energy costs from oil prices.

The European Commission adopted a communication proposing an energy policy for Europe, with the goal to combat climate change and boost the EU's energy security and competitiveness [8]. This set out the need for the EU to draw up a new energy path towards a more secure, sustainable and low-carbon economy, for the benefit of all users. Based on the European Commission's proposal, in March 2007 the Council endorsed the targets: to raise the share of renewable energy to 20% by 2020; to increase the level of biofuels in transport fuel to 10% by 2020; to improve energy efficiency by 20% by 2020; to reduce greenhouse gas emissions by at least 20% (compared with 1990 levels) by 2020 [3]. The promotion tasks of use of RES for energy production became a key element in energy policy of EU-27 Member States. There is large difference among individual EU Member States regarding the use of renewable energy [2,5]. For example, in EU-27 Member States as well as Sweden, Finland, Austria are leaders in this field comparing with others countries (France, Italy, Greece etc.).

In Lithuania, it is extremely important to use RES as widely as possible. The target is to increase the share of RES to at least 23% of country's final gross energy consumption by 2020. It will ensure the further development of heating and cooling, and electricity production from RES, implementation and development of production and use technologies in the transport sector and other actions [3,8]. It will help to reduce of amounts of pollutants (including greenhouse gas) emitted into the environment, to save of fossil energy sources, to reduce of the dependence on fossil energy sources and their imports and increase national energy security. To ensure that the mandatory national overall targets are achieved, EU Member States should work towards an indicative trajectory tracing a path towards the achievement of their final mandatory targets. In addition, as is indicated in Directive 2009/28/EC the EU Member States should set out measures to achieve those targets. EU Member States have different renewable energy potentials and operate different schemes of support for energy from renewable sources at the national level. The majority of Member States apply support schemes that grant benefits solely to energy from RES that is produced on their territory.

In this study we set out the renewable energy options available in Lithuania, their current status, the main positive results obtained to date and future potential. For the proper functioning of national support schemes it is vital that Lithuania can control the effect and costs of their national support schemes according to yours potential. The increase of use renewable energy improves the security of energy supply in Lithuania and also enables to reduce a greenhouse gas emission.

2. Energy sector in Lithuania

The energy sector of the Baltic States faces specific threats, yet it has valuable opportunities for efficient and reliable operation. With a more efficient use of the available opportunities and existing capacities, the energy sector of the Baltic States can achieve a more rapid economic development in the region, strengthen its competitiveness, reduce the possible threats and avoid unforeseen interruptions in energy supply. According to this Lithuania confronts a change in the power utilization structure with an emphasis on local and renewable power [9]. A major issue concerning the future development of the Lithuanian energy sector was the decommissioning of the Ignalina nuclear power plant (NPP) at the end of 2009, which was required for Lithuania's negotiations for joining the EU. The Lithuanian National Energy Strategy, in addition to EU directives and other documents, calls for the reduction of fossil fuel imports and for the reduction of atmospheric impacts caused by energy production. The focus is on promoting the use of RES and other indigenous energy sources and on increasing energy efficiency in all sectors of the country. Lithuania must also decrease the amount of imported fuel and become less dependent on fuel suppliers. Until 2010, the main Lithuanian power resources comprised imported fossil fuels and nuclear energy [10]. The primary energy utilization structure did not change considerably before the decommissioning of the Ignalina NPP (Fig. 1). Primary annual energy consumption between 2001 and 2009 varied from 8.22 to 9.22 Mtoe (toe is ton of oil equivalent, 1 toe = 11.628 MWh). In 2009, imported natural gas comprised 25.7% of the primary energy balance of Lithuania,

nuclear –30.3%, oil and oil products –29,9%, renewable energy –12.8% and coal and other solid fuels –1.9%. In 2010, after the decommissioning of the Ignalina NPP, the electricity deficit was satisfied by an increasing production of thermal power plants or by energy bought on the international market. Consequently, the consumption of natural gas for electricity production in the country increased. To reduce this dependency, the construction of a new NPP is planned in a joint project with Estonia, Lithuania and Poland. It will be located on the same site as Ignalina NPP was erected [11].

The share of renewable energy for EU-27 in gross inland consumption is more or less similar as in Lithuania (9.0% in EU-27 and 12.8% in Lithuania) (See Figs. 1 and 2).

All of the Baltic States have committed to reducing their greenhouse gas emissions to limit the negative impacts on climate change. Dependence on imports of primary energy resources is one of the most important concerns of the Baltic State governments, especially because a major part of their primary energy is imported from only one country (Russia). Under the Kyoto Protocol, Estonia, Latvia and Lithuania have taken on a target to reduce 8% greenhouse gas emissions (compared with 1990 levels) in the period from 2008 to 2020. To reach this target, attention must be paid to technological changes that provide major environmental benefits. Accelerating the use of renewable energy plays a major role in achieving the carbon dioxide reduction goal.

The environmental impact of renewable energy depends on how it is being used. For example, biomass plants produce some emissions, and fuel can be harvested at unsustainable rates. Wind farms change the landscape, and some have harmed birds. Hydropower projects, if their impacts are not mitigated, can greatly affect wildlife and ecosystems. However, these impacts are generally much smaller and more localized than those of fossil and nuclear fuels. Nevertheless, care must be taken to mitigate them.

3. A tendency towards renewable energy use in Lithuania

Currently, with energy demands constantly increasing and traditional ways of energy generation impacting the environment, the development of RES is very important. According to the Lithuanian national target, efforts will be directed to increasing the share of energy from RES to 23% in gross final consumption of energy in 2020, in order to implement international commitments and to meet the requirements of the EU directive (Directive 2009/28/EC, 2009). To achieve this goal, all types of renewable energy must be used, including solid biomass, wind energy, hydropower, biogas, biofuels for transport, etc [10,11]. For this reason, the consumption of RES is increased, independent of gross inland consumption of energy (Fig. 3).

Lithuania uses certain kinds of renewable energy that are traditional for the Baltic States, such as solid biomass (firewood, wood waste, straw), hydropower and other energies, which have the shortest payback time. Since 2001, there has been an important increase in the use of wind energy, biogas and other types. Additionally, Lithuania has erected pilot plants for geothermal energy, solar energy, etc. The most favorable conditions for utilizing local fuels are combustion of wood fuel, which has been used in Lithuania for ages. The wood fuel is the cheapest and most plentiful fuel in Lithuania and reduces the harmful emission of the burning equipments.

There are no considerable problems with using this energy source in small installations. The main proportion of heat energy in Lithuania is produced in large district heating systems that operate in all major cities and in many small towns. However, problems arise because, in the unstable fuel market, using local fuels in the larger systems causes technical and other problems. Until now, use of solid biomass has far outpaced the use of other renewable energy sources (Fig. 4). Biomass has been traditionally used by private householders for production of heat. There was burnt 529 ktoe worth of biomass in boilers of mostly

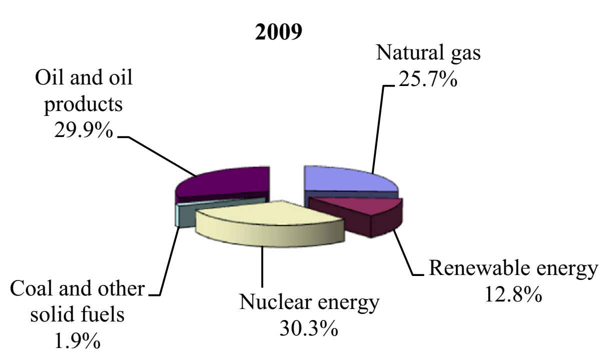


Fig. 1. Structure of gross inland consumption of energy before decommissioning of Ignalina nuclear power plant in Lithuania.

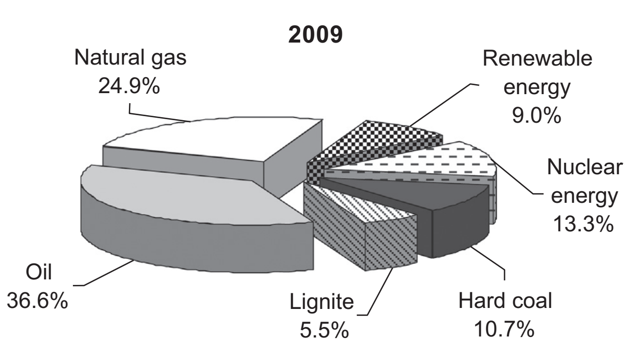


Fig. 2. Structure of gross inland energy consumption in EU-27.

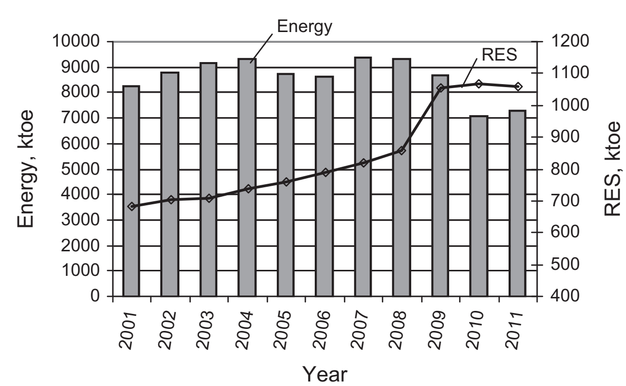


Fig. 3. Gross inland consumption of energy and renewables in Lithuania (ktoe is thousand tonnes of oil equivalent).

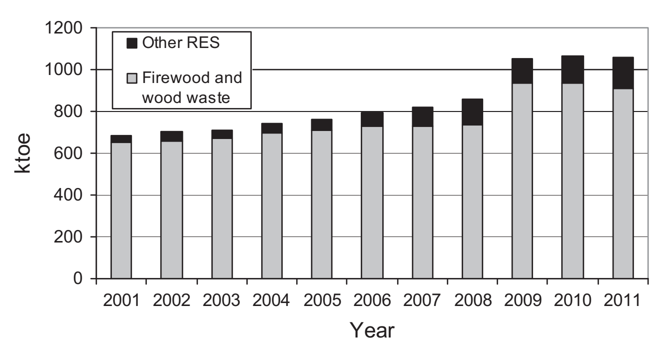


Fig. 4. Levels of renewable energy sources used for energy production.

low efficiency. A growing 135 ktoe worth of biomass were used in district heating, a technology reaching 75% of all Lithuanian residential buildings [11]. A geothermal heat plant supplies the district heating grid of the city of Klaipeda. It produced 4.5 ktoe worth of heat in 2010 [10].

3.1. Trends in renewable energy use

After restoration of independence in the Baltic States their energy sectors inherited from their Soviet past. Lithuania as well as the other Baltic States have comparatively typically well developed systems of natural gas supply. Since mid of 1970 s the natural gas imports come from a single source and are handled by the Russian natural gas monopoly "Gazprom". However, dependence on gas supply is one of the major concerns for the Baltic States, because possibilities for diversification of natural gas supply are very limited. Seeking to increase energy supply security construction of interconnections between the Baltic States, Scandinavian countries, Poland and increase the local fuels (peat, renewable energy, local oil etc.) is one of the strategic priorities in the region [9,11]. Finally a necessity to modernize power plants, district heating systems, electricity grids, pipelines and other physical installations in the energy systems is also common concern for Lithuania and other Baltic States.

Important alteration of the primary energy balance in the Baltic States is related with increased contribution of domestic energy sources and in particular of renewable energy. At the same time the share of renewable energy sources in the primary energy balance of Lithuania has increased even more significantly – about 2 times in period from 2001 to 2011, and in 2011 it was equal to 18.3%. As it is shown in Fig. 5, at present the bio-energy (fire wood, including wood waste, wood chips, sawdust, waste from agriculture, etc.) is the main renewable energy source in Lithuania. Finally growth of bio-energy consumption in Lithuania was the most stable during the period 1990–2011. Some potential for energy production from the renewable energy is closely related with increasing the use of new sources of the renewable as well as straw, wind energy, geothermal energy, solar photovoltaics etc. The use of biofuels (biodiesel and bioethanol) for transport needs has considerably increased.

3.2. Electricity production from renewable energy

In Lithuania, the production of electricity from RES is based on large-scale (installed capacity more than 10 MW) and small-scale (installed capacity less than 10 MW) hydropower plants (HPP), wind energy and biomass and biogas combined heat and power (CHP) generation or cogeneration in district heating plants or for industrial processes. The last installations of biomass combustion equipment in thermal power plants significantly increased electricity production by biomass and the total installed capacity reached 18 MW. There are also some cogeneration units for biogas combustion [11–13]. Electricity produced from RES comprises 9.53% of the total electricity consumption in the country (Table 1).

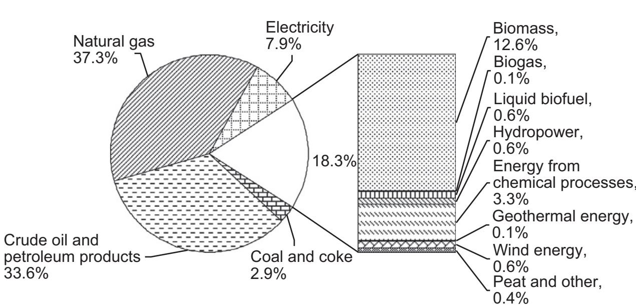


Fig. 5. Structure of gross inland consumption of energy in Lithuania in 2011.

Table 1
Gross electricity production by renewable energy sources in Lithuania in 2011.

Type of plants	Installed capacity of equipment (MW)	Fuel	Production in 2011 (TWh)	In 2011, share of total electricity consumption (%)[a]
Kauno HPP[b]	100.8	Water	0.386	3.33
Small HPP	28	Water	0.094	0.81
Wind energy	179	Wind	0.475	4.11
Biomass plants	18	Wood waste, chips, sawdust	0.116	1.01
Biogas plants	13	Biogas	0.031	0.27
Total	338.8		1.102	9.53

[a] In 2011, the gross electricity consumption was 11.56 TWh.
[b] HPP is Hydropower plant.

CHP can help reduce energy costs, improve the business environment, support energy infrastructure and improve energy security and power reliability, all while offering environmental and climate change benefits. Because the district heating sector in Lithuania is developed enough good so that there will be no problem in installing cogeneration equipment for biomass combustion. Other kinds of renewable energy, such as geothermal energy and photovoltaic electricity, are not used widely in Lithuania [10].

4. Renewable energy policies in Lithuania

A comprehensive policy of alternative energy use has been formulated by the Lithuanian Seimas (Parliament) through the National Energy Strategy [9] and other documents, the laws created by the Lithuanian Seimas and the governmental programs and resolutions [14,15]. These documents evaluated the requirements of the directives of the European Parliament and Council, the United Nations (UN) Framework Convention on Climate Change (FCCC) and other documents compliant with the EU environmental policy.

The most important participants for enhancing the utilization of RES include government organizations, non-governmental organizations (NGOs), universities and private institutions. In Lithuania, there are different institutional structures at various levels. Objectives were set and actions were taken through high priority national, regional and global projects.

4.1. Role of the government

The government obligates the ministries, departments, state services, companies, offices and other organizations to comply with the main objectives of the National Energy Strategy. The Ministry of the Economy is responsible for the implementation of energy plants for the combustion of wood waste and straw, the production of biogas and the utilization of other sources of renewable energy. The Ministry of the Environment is responsible for organizing the production of wood chips, evaluating wood resources in Lithuania, rendering assistance for growing short-rotation forests and preparing and confirming legal acts related to biofuel production and usage in Lithuania. The Ministry of Agriculture is responsible for helping to implement the production of biofuels and growing energy crops. The Lithuanian government prepared the main acts for promoting renewable energy use in the country. Municipalities are responsible for the coordination and implementation of up-to-date technology within their regions.

The state company "Energy Agency" (SC EA) is responsible for coordinating research, development and implementation of renewable energy plants. The incorporator of SC EA is the Ministry of the

Energy of the Republic of Lithuania. The SC EA deals with drafting the National Energy Strategy, improving the efficient use of energy resources and using local, renewable and waste energy resources. SC EA is responsible for international cooperation in the energy sector, coordinating foreign technical assistance to the energy sector in accordance with the priorities laid down in the National Energy Strategy and National Energy Efficiency Program, organizing and supervising the harmonization of Lithuanian legislation and European Union legal requirements and participating in the integration of energy sectors in the Baltic States and Baltic Sea States.

4.2. Energy legislation structure for renewable energy

The program to promote biofuel production and the procedure for promoting the generation and purchase of RES electricity were prepared and accepted by the government [15,16]. The main tasks of this Program are to augment the production of electricity from biogas, wood and straw, to produce biofuels for transport from raw material originating in the Republic of Lithuania and to promote the growing and preparation of raw material for biofuel and other renewable energies.

To achieve such ambitious objectives, the government also intends to ensure that renewable energy becomes competitive in the internal electricity market in the medium- to long-term. Regulations for the use of RES for energy production are included in the laws accepted by the Lithuanian Seimas [17–20].

The Law of the Republic of Lithuania on Energy regulates general energy activities, the basic principles of energy development and management, security of energy supplies, reduction of adverse effects from energy activities on the environment, energy and energy resources efficiency and promotion of consumption of indigenous and renewable energy resources [17]. According to the law, the state institutions and agencies shall have a right to obtain relevant information from energy enterprises for the performance of the functions assigned to them. Energy enterprises shall provide, in accordance with the established procedure, information to state and municipal institutions, agencies, appropriate associations and third parties. The Government, or institutions authorized by it, shall provide energy-related information to the European Commission, other countries and international organizations. Energy enterprises shall, within the limits of their competence, provide energy consumers within the territory of their operation information about the efficiency of energy resources, safe and effective use of energy facilities and equipment, energy facilities and installations under construction or reconstruction, energy tariffs and the services provided to energy consumers.

The law regarding biofuel, biofuels for transport and bio-oils states that the Republic of Lithuania shall regulate the legal conditions of the production and use of biofuel, biofuels for transport and bio-oils [18]. The objectives of this law are the following: to promote the production and use of biofuel, biofuels for transport and bio-oils (taking into account the requirements of the legal acts of the European Union and the international commitments of the Republic of Lithuania), to reduce the dependence of the national energy sector on fuels produced from mineral resources and imported raw materials, to increase the efficient use of local, renewable and alternative energy resources and to increase the security of the energy supply. By coordinating their actions with municipalities and scientific and educational institutions, the Ministries of the Environment, Transport and Communications, Education and Science, Economy, and Agriculture shall prepare measures to inform the public, promoting the use of biofuel, biofuels for transport and bio-oils. The Government, or an institution authorized by it, shall designate the procedure for reporting to the European Commission on the use of biofuel. For the fulfillment of the assigned functions, state institutions and agencies shall have the right to obtain from municipalities, agencies and enterprises the necessary information about the production and use of biofuel, biofuels for transport and bio-oils. Enterprises shall furnish information about the production and use of biofuel, biofuels for transport and bio-oils to municipal institutions and agencies to fulfill the functions assigned to them.

The Law on Electricity of the Republic of Lithuania promotes the consumption of electricity produced from local, renewable and waste energy resources, and article 11 claims that "*the State shall encourage customers to purchase the electricity produced from local, renewable and waste energy resources*" [19].

The Law on the Heat Sector of the Republic of Lithuania resolves that the state (municipalities) shall promote the buying of heat for heat supply systems produced from biofuel, other sources of renewables, waste incineration and geothermal energy [20].

5. Promotion of renewable energy

In Lithuania, there are fixed purchase prices for electricity produced by RES. Lithuania uses the feed–in tariffs model for purchasing green electricity [15,21]. According to legislation, electricity suppliers must purchase the electricity produced from RES in Lithuania up to, but not exceeding, the established government quota. According to the quota, there is a fixed purchase price 12 years or some cases it can be longer. It depends from the installation cost of the energy production equipment and its payback time. The quota obligation does not include the electricity produced by wind turbines with a capacity less than 30 kW. The price for purchasing electricity produced by renewable energy constantly increases because the government seeks to increase investment in the renewable energy sector. There is also a discount for wind turbines and for the purchase of other equipment for the connection of renewable sources to the energy production grid. The subsidy for the connection cost might constitute up to 40% of the connection-to-grid cost. The distribution system operators are obligated to organize competitions (auctions) of permits for investors intending to build electricity production plants using renewable energy. In the case of wind plants, the auction will be for the permit to a specific wind zone. The winner obtains the permit to build a wind turbine or a wind turbine farm. The criterion for the competition is the largest bid for contribution to a plant's connection cost. For example, the bid might be for at least 60% of total connection cost. The grid operator pays to the investor the difference between 100% of the connection cost and the bid that won the competition (auction). The "Green certificates" system is planned for 2021.

There are some promotion measures to encourage the use of biofuels for the transport sector. They are

- *tax exemptions and deductions*;
- *blending requirements*.

There is also financial assistance from the government and local authorities, through grants, loans, tax exemptions and deductions, for installing equipment for energy production using renewable energy. Municipalities have opportunities to incorporate renewable energy schemes into infrastructure development projects (waste water treatment, municipal waste, heat supply, energy conservation in municipal buildings, municipal transport, etc.). If included in the Special Governmental Program, these municipal projects are financed (granted) by special donations from the State budget. Municipalities may approve their own special program for promoting renewable energy and finance them from their own budget, but, generally, this opportunity is not financially viable. Private enterprises have the ability to initiate renewable energy investment projects, mainly in the public sector, by

submitting the investment project proposals to a state institution, municipality or state body.

6. Implementation status of the renewable energy technologies

In Lithuania, as well as in other EU Member States, the use of a solid biomass for heat production is most popular. Also the geothermal energy and heat pumps become more popular for heat production. The data given on the Table 1 show that electricity is mainly produced in hydropower plants, by wind energy and in CHP plants. In the last time the solar photovoltaics (PV) was begun to use, the pilot solar PV plants were installed.

6.1. Solid biomass energy

6.1.1. Wood waste

All Baltic states, as well as Lithuania, could be characterized as a region with rich forests and the potential for future development of renewable energy. From 1998 to 2008, the forest coverage in Lithuania increased from 30.3% to 31.3%. The forest area is 2045.3 kha [22]. Annual current increments in Lithuanian forests were 12.0 million m^3 during the last five years. Firewood and wood waste are being used, and the total amount for energy is 4.55 million m^3 solid volumes plus felling waste. The available forest fuel resources depend on the increment of the forest's biomass, the price of fuel, the complexity of the burning equipment and the burning price. Consumption is influenced by the price, which depends on several factors: available forest resources and level of cutting, forestry operations for commercial- and pre-commercial thinning, the situation in the wood market, harvesting technologies, cost of labor, the tax system and consumption of wood by sawmills and other forest industry enterprises. The feasible potential is thought to be 9.8 TWh per year. The installed capacity is about 385 MW for heat production by solid biomass, which is used for heat supply in Lithuanian district plants, and 18 MW for electricity production equipment in CHP. Lithuania is also a producer of wood fuel products, in addition to pellets and briquettes. However, the pellets are not used successfully in the local market because they are too expensive to be used by the local consumers. The sawdust pellets are exported to Denmark, Germany, Norway, Sweden and other countries.

6.1.2. Straw

One potential area for increasing energy production from renewable energy sources is closely related to the increasing use of straw. Depending on the Lithuanian agricultural policy, the total straw production in 2020 could be about 3 million tons per year. The technical potential, excluding consumption on farms and other needs and losses, is assessed at 1.7 million tons, or about 6.95 TWh; however, the feasible potential, according to calculations and investigations by local and foreign scientists, is 1.5 TWh in 2020 [23]. The installed capacity of straw combustion boilers for heat production is about 12 MW [13].

6.2. Biogas energy

6.2.1. Biogas

Reliable sources of biogas include those from agriculture (manure from poultry and farm animals), food processing (organic wastes) and municipal wastewater treatment plants (with their methane tanks for anaerobic digestion). The largest potential source could be from agriculture, but total feasible annual production of biogas is thought to be only 0.28 TWh [23]. Lithuania also has some pilot cogeneration plants installed: 275 $kW_{el.}$/600 kW_{heat} in a Wastewater Treatment Plant in Utena, 750 $kW_{el.}$/1500 kW_{heat} in a Wastewater Treatment Plant in Kaunas, 600 $kW_{el.}$/900 kW_{heat} in a Company “Lekeciai” in Lekeciai and 2 units at 165 $kW_{el.}$/264 kW_{heat} in JSC “Rokiskis suris” in Rokiskis [13].

6.2.2. Landfill gas

It is possible to capture the biogas from the country's landfills. In Lithuania in 1998, there were 292 official landfills. Twelve of those landfills have a volume over 500,000 m^3 and store approximately 22 million m^3 of municipal waste. Assuming a density of 0.55 t/m^3 waste in the landfill, the total amount of waste in the 12 landfills is estimated to be 12.1 million tons. The respective yield of methane could be about 24 million m^3 per year, with a thermal energy equivalent of 0.1 TWh. Currently, landfill gas is used in the pilot plant of Domeikava village which was erected in 2008. The CHP plant has an installed capacity of 1200 $kW_{el.}$/1500 kW_{heat}. The biogas is produced in a landfill near the settlement of Lapes and it was used in the pilot plant. The rapid implementation of other landfill gas projects is expected. Landfills near the towns of Vilnius, Klaipeda and others could be used for new project installations. The available methane resources are sufficient for the CHP installation, with electrical power up to 2.0 MW. After the erection of a collection system for landfill gas in Vilnius (landfill of Kariotiskiai) and Siauliai (landfill of Kairiai) will be possible to erect equipment with a capacity of 4 MW and able to produce 0.0417 TWh of energy. In the future, only the regional landfills will be left and the gas capture will be obligatory. It will be possible to install equipment with a 9 MW capacity. Feasible energy production will be 0.1 TWh/year.

6.3. Wind energy

Lithuania has old traditions for using wind energy. The most favorable wind energy potential is located in western and north-western Lithuania. Wind energy can be efficiently harvested in zones where the average wind speed at 10 m above the ground exceeds 5–6 m/s [24]. In Lithuania, such zones are situated mostly at the Baltic seacoast. From an economical point of view, the most efficient wind turbines would be large-sized plants installed offshore or close to a coast. Design activities are already in preparation.

Until 1940, there were approximately 1000 windmills, but they were destroyed during the postwar time (from 1945 to 1990). The development of wind energy has started only in the last few years. The first wind turbine (630 kW) was installed in 2004. In 2006, the first wind park of 11 turbines (installed capacity 2 MW each) was erected and connected to the electricity network. The target for the wind turbine installation capacity is 500 MW for 2020. There are large environmental constraints for installing wind parks, and the electricity network needs to be improved. At the end of 2005, the total capacity of all installed wind turbines was 6.4 MW, but at the end of 2011, it reached 179 MW [13].

6.4. Hydro energy

The technical (or real) potential of hydropower resources is estimated to be as large as 1.5 TWh per year. One TWh of resources is concentrated on the big Lithuanian rivers, Nemunas and Neris, and the remaining 0.5 TWh is located on the middle and small rivers (total, 470). The large hydropower plants seem to have greater importance, but their construction is only feasible in the long-term future due to big investment costs and environmental restrictions. Small-scale hydropower plants (with a capacity less than 10 MW) have become commercial and profitable. There have been several new, small-scale hydropower plants built during recent years. In Lithuania, one large HPP and about 83 small HPPs have been installed. The capacity of Kaunas HPP is 100.8 MW, and it works successfully about 50 years.

The installed capacity of the small-scale HPPs is 28 MW, with an annual production of about 65 GWh. Construction of new hydropower plants is limited by landscape features and the necessity to use rivers for recreational needs. In recent years, more restrictions on the erection of small-scale HPPs on small rivers were passed by the government. In Lithuania, an increase in hydropower will come mostly from small power plants. The real potential of electrical production from hydropower plants must be revised after the government's political decision.

6.5. Geothermal energy

Geothermal power and solar photovoltaics, whose costs are rapidly falling, are more dependent upon market conditions, delegated legislation and financial support of the government [25,26]. The first geothermal wells of Lithuania were drilled in Vydmantai at the year 1989, their depth of more than two kilometers. Wells were tested in 1993–1994 years, the geothermal water temperature reached 74 °C. But the tests were closed because Lithuania had the big financial difficulties.

In 2000 Klaipeda Geothermal Demonstration Plant, with a 41 MW capacity for heat supply, was installed. According to the project, generation of heat energy consists of 41% geothermal energy and 59% gas energy for reheating water, which was used for district heating. The plant uses 38 °C water from the well drilled about 1100 m beneath the surface. The heat was extracted using an absorption heat pump. It was the first geothermal heating plant in the Baltic Sea region. The project's total energy generation is 0.27 TWh/year. Construction was completed in 2001. Now, the Klaipeda geothermal plant is working on the installed capacity.

It is also possible to use geothermal energy in other regions of Lithuania. Geothermal energy resources are concentrated in the western region of Lithuania. Geothermal energy can best be used for heat generation. It is possible to erect binary cycle geothermal power plants because Lithuania only has low temperature (below 130 °C) geothermal hot water. There are some technical and economic difficulties in constructing the geothermal power plants until 2020. Perhaps in the future, these power plants will be erected in the Klaipeda and Birzai regions of Lithuania.

The Lithuanian geological institute evaluated the geothermal resources and established that the feasible potential of geothermal energy is 0.8 TWh/year. The environmental impact of geothermal energy is small as compared to that of hydrocarbons. Energy prices and environmental impacts are the main factors which will establish the geothermal energy use in Lithuania and in other Baltic states.

6.6. Solar energy

In Lithuania the solar energy is used for the heat and electricity production. In 2011 the new Law on Renewable Energy Sources of Lithuania Republic was accepted by Lithuanian Seimas [21]. Until this new Law was accepted in Lithuania any photovoltics equipment connected to the electricity grid was not installed. After that during two years at the end of 2012 40 solar plants were installed. The goal of Lithuania is to reach the installed equipment with total capacity for 40 MW in 2020.

Solar thermal energy: Lithuania is situated between latitudes 54° and 56° North. Annual average radiation of for one square meter is 1000 kWh solar energy. Solar collectors can be installed for water heating, drying of agriculture products and space heating of premises. Several solar collector systems for water heating have been already installed, total area of collectors being 3000 m^2. The biggest area of solar systems reach 160 m^2 Polyethylene solar collectors were developed and started to use for drying purposes in agriculture. Their seasonal efficiency amounts to 200 kWh/m^2. Total square area of collectors of this type is about 180 m^2. In year 2003 the first demonstration project was implemented in children sanatorium: 78 m^2 of solar collectors supplied energy for water heating. It should be noted that solar energy is not commercial as yet. It is more expensive as traditional one. For this reason the new installations of solar collectors increase slowly in Lithuania.

But in 2011 a big solar energy system was installed in Kruonis hydro accumulation station which can produced energy of 70 MWh per year. The vacuum and flat plate solar collectors are used for energy production which is used for the heat water production. It is evident that the solar energy can be used for the heat production in Lithuania.

Solar electricity: Photovoltaics (PV) are a technology that converts light directly into electricity. The amount of useful electricity generated by a PV module is directly proportional to the intensity of light energy that falls onto the conversion area. So, the greater the available solar resource, the greater is the electricity generation potential. To capture as much solar energy as possible, the PV cell must be oriented towards the sun, and shading must be avoided. In Lithuania, the efficiency of commercial solar cells converting solar radiation energy into electricity is about 15%, about 20% for experimental cells and 30% in experiments with multi-junction semiconductors. Approximately 150 kWh/m^2 of electrical energy can be produced annually from one square meter using modern commercial solar cells. PV power systems began to be used in 1970, after the world energy crisis, for both residential and commercial use and for stand-alone, remote power and utility-connected applications. International applications for PV systems, including powering rural health clinics, refrigeration, water pumping, telecommunications and powering off-grid households, increased and now remain a major portion of the present world market for PV products. Today in Lithuania, PV modules are used mainly for supplying power to electronic equipment directly also connected to the power grid. The first commercial pilot PV plant of the capacity 0.0179 MW was installed in the end of 2010 near Vilnius. In 2011 the Renewable energy law [21] was accepted by Lithuanian Seimas. Additional measures for promoting of solar PV were included and the installations of solar PV very increased. In the end of 2012 the installed capacity of solar PV reached 7.43 MW, and generated 2.3 GWh of electricity energy.

In 2008 JSC "Precizika SC-MET" has been established. The main area of activities – solar cell manufacturing process technologies. The company has launched first Lithuanian pilot solar cells production line in its Industrial Photovoltaic Laboratory. The equipment, installed in the Laboratory, together with advanced test and measurement equipment enables to master and successfully commercialize fundamental technologies created in scientific research institutions, thus ensuring that only commercially and cost effective technological solutions, already perfected in the laboratory, would be implemented into production. The laboratory focuses on two main areas: R&D activities and services. R&D direction includes monocrystalline silicon solar cell research and development of new technologies. Equipment in the laboratory are projected up to 1 million solar cells annual production capacity (about 100 MW)

6.7. Municipal waste

Energy from municipal waste is possible using a waste to energy plant. This can be done by different methods, including incineration, gasification, pyrolysis, and anaerobic digestion. Investigations show, that the incineration reduces the need for landfills and extends the life of existing landfills [27]. This means that the negative effects of landfills are reduced and that municipal councilors can, as a result, avoid the usually politically risky search for new landfill sites. Municipal waste management has become even more important because many of the landfills in Baltic countries as well as in Lithuania are becoming full, and a number of them have already closed. According to investigations by the

National Energy Efficiency Program, the annual potential of municipal waste in Lithuania to power district heating systems is 0.8 TWh of energy. The municipalities of Lithuanian cities are interested in combustion of garbage in boilers. It is expected that the pilot boiler-houses fueled by municipal garbage for energy generation to be introduced towards the end of 2011.

6.8. Liquid biofuels

The EU Directive 2003/30/EC, on the promotion of the use of biofuels or other renewable fuels for transport, is a basic document detailing the Lithuanian policy for biofuels until 2010. Transport fuel gross consumption in Lithuania in 2010 was 1306.7 kt (kt) (10,112.0 kt of diesel fuel and 295.7 kt of gasoline). The goal for the minimum share of biofuels for the total consumption of transport fuels in 2005 and 2010 was 2% and 5.75%, respectively. Timely this target was implemented in Lithuania. Biodiesel is produced using rapeseed oil and ethanol from grain (wheat, triticale, rye, etc.).

Currently, rapeseeds are grown in an area of 80 thousand ha; however, the program “Developing of rapeseeds cultivation and inhabitants maintenance with nutritional oil” states that there is a possibility to use a much bigger area, of around 230–290 kha, for cultivation of rapeseed in Lithuania, which will not infringe on the agriculture production for the feeding. Because 50 kha of rapeseed would be sufficient for nutritional oil production, the rest of the area could be used to cultivate 540–720 kt of rapeseed to produce 178–230 kt of oil for biofuel production. In addition to this, there would be around 500 kt of oil-cake (rapeseed-cake) produced, which is valuable as a fodder additive and would be able to substitute the imported soy fodder. Approximately 34 kt/year of ethanol is produced in Lithuania; however, production capacity is twice as large. Ethanol produced from a grain surplus and other agricultural products could be used for blending with gasoline. Technological processes for biofuel production are sufficiently investigated and implemented in all EU Member States, including Lithuania, as the EU directives give them tax privileges for the use of biofuels.

7. Renewable energy environmental impact

In 1992 Lithuania together with 154 other countries has signed the United Nations (UN) Framework Convention on Climate Change FCCC in Rio de Janeiro and other documents compliant with EU environment policy. Lithuanian Parliament ratified the Convention in 1995 and the Lithuanian Government approved FCCC National Programme in 1996. Its major goals are reduce the climate change impact and cut the CO_2 emissions as well as address other environmental issues. According to the Kyoto Protocol, which was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005, Lithuania must reduced from 2008 to 2012 greenhouse gas emissions 8% compared with level on 1990. It is possible to achieve this goal by increasing of use all kinds of renewables. The increase of use RES is a central aim of Lithuanian energy policy, because RES has an important role to play in reducing CO_2 emissions (Table 2). Contribution of a given greenhouse gas (GHG) is reported as a CO_2 equivalent. Equivalent CO_2 is the concentration of CO_2 that would cause the same level of radiative forcing as a given type and concentration of greenhouse gas. The increase of the use renewable energy helps to improve the security of energy supply by reducing the country's growing dependence on imported energy sources. Moreover, RES are expected to be economically competitive with conventional energy sources in the medium to long term.

Increasing the share of RES in the energy balance enhances sustainability. It also helps to improve the security of energy supply by reducing the country's growing dependence on imported energy sources. Moreover, RES are expected to be economically competitive with conventional energy sources in the medium to long term. Currently, in Lithuania is used the imported fossil fuels as well as a crude oil, petroleum products, a natural gas, electricity and coal and coke. The local fuel as well as renewable energy sources compromises 18.1% and peat and other compromises 0.2%. The share of wood fuel compromises about 88% all renewable energy resources used in our country. In 2020, the cut of the CO_2 emissions can be achieved about 10.60% compared with the level on 1990 when the crude oil will be changed by renewables and 7.68% when the natural gas will be changed by this one. It is evident that Lithuania can achieve the requirements of the Kyoto Protocol only to increase the use all kinds of RES for energy production.

8. Conclusions

The increase of the use of renewables, particularly energy from biomass, wind, water and solar, is a central goal of the Lithuania's energy policy because renewable energy has an important role for reducing CO_2 emissions and it also helps to improve the security of energy supply by reducing the country's growing dependence on imported energy sources. Moreover, renewables are expected to be economically competitive with conventional energy sources in the medium to long term.

Until 2010, Lithuania's primary energy resources consisted mainly of imported fossil fuels and nuclear energy. At the end of 2009, the Ignalina nuclear power plant was decommissioned and Lithuania faces a power utilization structure change with an emphasis on local fuel and renewable energy.

In Lithuania, the main systems for heat production from renewables are concentrated on solid biomass (wood, chips, wood waste, straw, biogas). No serious obstacles are expected for the expansion of wood as a fuel source. Until recently, power generation was mainly focused on hydropower. In 2010 and beyond, there will be an increase in the use of wind energy and biomass in CHP for power production. In 2011, the total capacity of installed wood-chip-fueled boilers was above 385 MW and the capacity of wind turbines increased to 179 MW. The capacity of power

Table 2
Current status and prospect of use renewable energy and reduction of global carbon dioxide (CO_2) emissions (kt and percent compared with 1990 level).

Year	2001	2005	2009	2010	2011	Prospect 2020
RES use, (ktoe)*	682.40	758.70	1052.60	1067.10	1058.10	1770.00
Reduction of emissions when a fossil fuel is oil (kt)**	2209.61	2456.67	3408.32	3455.27	3426.13	5731.26
Percent	4.09	4.54	6.30	6.39	6.33	10.60
Reduction of emissions when a fossil fuel is natural gas (kt)	1601.59	1780.67	2470.45	2504.48	2483.36	4154.90
Percent	2.96	3.29	4.57	4.63	4.59	7.68

In Lithuania in1990, the global carbon dioxide (CO_2) emissions were 54,089 kt.

* toe is ton of oil equivalent.

** *t* is ton.

production plants by solid biomass increased to 18 MW and also solar photovoltaics (PV) for power production began to use. The installed capacity of PV plants increased to 6.44 MW in the end of 2012 year.

In 2011, the renewable energy sources in Lithuania compromise 18.1% of gross inland consumption of energy and cut of the CO_2 emissions about 6% compared with the level on 1990. According to the Kyoto Protocol Lithuania must reduced green gas emissions 8% in the period 2008–2020. It is evident that renewable energy will help to reach this goal.

The use of biofuels is based on the EU Directive 2003/30/EC, which promotes the use of biofuels for transport, and on the Lithuanian energy strategy. These regulations state that the minimum share of biofuels must be 5.75 and 15% from the total consumption of transport fuels in the years 2010 and 2020, respectively. In Lithuania, biofuels are blended with oil products.

Implementation of renewable energy projects is of importance to Lithuania because fuel importation and CO_2 (and other) emissions will be reduced and more jobs will be created in the energy field. Additionally, to speed up the usage of renewables for energy production, it is necessary to invest more in energy production equipment and to promote the introduction of new technologies to ensure efficient use of the resources and to adapt the existing equipment to renewable energy.

The main driving forces for the development of renewable energy in the energy conversion sector and the production of biofuels are the general energy policy in Lithuania, a favorable legislative framework and implementation of the EU Directives and the corresponding National Programs. The most important obstacles for faster growth of renewable energy use are high investment costs, long pay-back periods for projects, financial resources necessary to implement governmental policies and a comparatively fast increase in prices for alternative fuels.

References

[1] Action Plans and Forecasts. Available at: ⟨http://ec.europa.eu/energy/renewables/action_plan_en.htm⟩.

[2] Renewable energy. The contribution of renewable energy up to 12.4% of energy consumption in the EU27 in 2010. STAT/12/9418 June 2012. Eurostat News Releases on the internet: ⟨http://ec.europa.eu/eurostat⟩.

[3] Directive 2009/28/EC of European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal L140, 16–62; 5 June 2009.

[4] Roubanis, N. Renewable energy indicators. Eurostat, Data in focus 30/2010.

[5] Sturc M. Renewable energy. Analysis of the latest data on energy from renewable sources. Environment and energy. Eurostat, Statistics in focus 44/2012.

[6] GWEC. Global wind statistics; 2011. (07.02.2012).

[7] WWEA.World Wind Energy Report; 2011. (May 2012).

[8] An Energy Policy for Europe. COM; 2007 1. Brussels, (10.1.2007).

[9] Lithuanian Energy Institute. National Energy Strategy, 2007. (Approved by Lithuanian Republic Seimas, Resolution No IX-1046 of 18 January, 2007). Vilnius.

[10] Statistics Lithuania, Energy Balance 2010. Vilnius; 2011.

[11] Rosede, D. et al. REPAP 2020. Renewable energy industry roadmap for Lithuania. Project of Fraunhofer ISI and Vienna University of Technology; 2010.

[12] Katinas V, Markevicius A. Promotional policy and perspectives of usage renewable energy in Lithuania. Energy Policy 2006;34(7):771–80.

[13] LITGRID Reports. Available at: ⟨http://www.litgrid.eu/index.php?1973822023⟩.

[14] Ministry of Economy of the Republic of Lithuania. The National Energy Efficiency Program (NEEP); 2007: Vilnius.

[15] Amendment of Resolution No. 627, 2005. Procedure on promotion of generation and purchase of electricity generated using renewable and waste energy sources (Resolution of the Government of Republic of Lithuania. 13 January 2004, No. 25). Valstybes zinios 2005; No. 73–2651 Vilnius.

[16] Government of the Republic of Lithuania. The program for the promotion and use of biofuel in 2004–2010.Valstybes zinios; 2004; No. 28-870 Vilnius.

[17] Law on Energy of the Republic of Lithuania. Valstybes zinios; 2002; No. 56-2224 Vilnius.

[18] Law on biofuel, biofuels for transport and bio-oils of the Republic of Lithuania. Valstybes zinios; 2003; No. 51-2254 Vilnius.

[19] Law on Electricity of the Republic of Lithuania. Valstybes zinios; 2000; No. 66-1984 Vilnius.

[20] Law on Heat Sector of the Republic of Lithuania. Valstybes zinios; 2003; No. 51-2254 Vilnius.

[21] Law on Renewable energy sources of the Republic of Lithuania. Valstybes zinios; 2011; No. XI-1375 Vilnius.

[22] Ministry of Environment, State Forest Survey Service. Lithuanian Statistical Yearbook of Forestry; 2008. 2009 Kaunas.

[23] Danish Energy Authority. Enhancement of Use of Local and Renewable Energy Sources. Evaluation of the Potential of Renewable Energy in Lithuania. Report Danish Energy Management A/S, December 2003.

[24] Markevicius A, Katinas V, Marciukaitis M. Wind energy development policy and prospects in Lithuania. Energy Policy 2007;5(10):4893–901.

[25] Overview; 2008. Energy for the future: renewable sources of energy. Available at: ⟨http://ec.europa.eu/energy/res/index_en.htm⟩.

[26] Solar Energy; 2008. Available at: ⟨http://saule.lms.lt/main/solar_e.html⟩.

[27] Wade A, et al. An assessment of the current and future options for domestic waste Management in Kaunas, Lithuania. Waste Manage Res 2006;24(1):27–36.